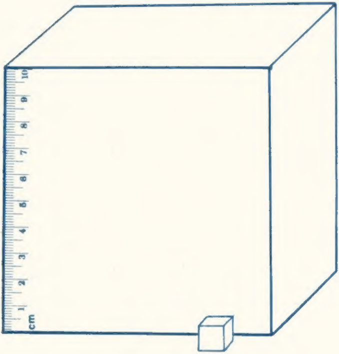
# THINGS

# of science




## METRIC SYSTEM

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# METRIC SYSTEM

Mrs. Smith, the mother of two children, a daughter 10 and a son 12 years old, was very proud that her son John, 183 centimeters tall and 83 kilograms in weight, had made the varsity football team in his high school, and much relieved that he had regained the 4.5 kilograms he had lost during his recent bout with the flu.

This morning she was on a shopping trip for immediate needs. She went first to the yard goods store to buy 2.5 meters of printed cotton cloth for a dress her daughter Mary had asked her to make for a school play and a package of 50-millimeter-long embroidery needles. Then she drove to the drug store in a shopping center about one kilometer away to purchase a 280-gram bottle of hand lotion and a package of Band-Aid. Next door at the stationers she bought some 7.5 x 12.5 centimeter file cards for her recipe box and for Mary a sheet of light blue poster paper for an art project. She had been told the paper must be at least 50 centimeters wide and 68 centimeters long and had to search through several shelves before locating the correct size.

Mrs. Smith then walked a few doors

further to the hardware store to get a 4 liter can of white enamel paint for her kitchen and a 5 meter electric extension cord needed in her husband's workshop.

Finally she stopped at the grocery store for a two liter carton of milk, 1½ kilograms of hamburger, a dozen rolls and ¼ kilogram of cheddar cheese. She also picked up a head of lettuce and a 500 gram loaf of bread. Then noticing a special on the 500 gram package of potato chips, she bought that too.

As Mrs. Smith drove the 10 kilometers back to her home, she thought of the beautiful 3 x 4 meter rug she had seen in the furniture store. She would discuss the purchase of the rug with her husband that evening.

When she turned into the residential area, she slowed to the 40-kilometer-per-hour speed limit. As she entered her driveway, she admired her crocuses now 6 centimeters tall growing along the fence, telling her spring was at hand, although the temperature was still a chilly 10° Celsius.

* * *

Can you visualize the measurements given in the narrative above or are you confused? If they are meaningful to you, you are familiar with metric terms and can relate them to your daily life. If not, you are among the majority to whom the metric system is still a textbook language primarily for scientists and technologists.

However, we are steadily approaching a future in which the metric system of weights and measures will predominate in everyday life; first, because it is much simpler than our present system, the U.S. Customary System, and secondly because of its almost universal use in international trade. The United States is now the only major country that has not completely converted to the metric system. But conversion is slowly taking place in America, especially in industry where different companies realize the economic advantage of a common international standard of measurements. Also, as you shop, you will find that more and more items give amounts in both the customary and metric systems.

It is to our advantage to familiarize ourselves with the metric system and to be able to visualize the length and weight of objects given in metric terms directly without resorting to mental arithmetic or

pencil and paper to convert centimeters into inches or grams into ounces. Such an ability can be readily achieved with a little practice.

The materials and experiments in this unit will help you "think metric" and prepare you for the inevitable metric future.

First look over your materials.

LEAFLET—"Brief History of Measurement Systems" containing a chart of the modernized metric system, by the National Bureau of Standards.

LEAFLET—"All You Need to Know About Metric," by the National Bureau of Standards.

15 CENTIMETER RULER—Includes inches.

CONVERSION CARD—Credit card-size metric conversion chart.

PAPER CLIPS—Two.

POLYETHYLENE BAGS—Two.

DIAGRAM—One meter stick.

DIAGRAM—Speedometer chart in kilometers and miles.

## THINK METRIC

In the leaflet "Brief History of Measurement Systems," included in this unit, you will find the story of the development of weights and measures in the U.S.

Customary System and also the history of the Metric System and its status in the United States today. Read it carefully and familiarize yourself with the metric terms.

Examine the chart of the International System of Units (SI), the modernized version of the metric system established by international agreement. Observe that there are seven base units and two supplementary units. Some of the units are already familiar to you.

Now look at "All You Will Need to Know About Metric" and note the units that apply to everyday life. Notice that the temperature term commonly used is Celsius rather than Kelvin of the seven base units. Celsius is the same as the former centigrade thermometer. It is called Celsius after the Swedish Astronomer who originated the centigrade scale. In this scale, the interval between the freezing point of water, designated 0°, and the boiling point, 100°, is divided into 100 equal parts or degrees.

As we go about our daily activities, we are constantly measuring things around us although we may not always be doing so consciously in inches, feet and yards. But we do obtain an impression of the sizes of many objects we happen to see,

and if asked about the size, we can usually give fairly accurate measurements of what we observe, such as a desk 5 feet long and 3 feet wide, a friend about 6 feet tall, a book about 10 x 6 inches in size or a tree 40 feet tall, without making actual measurements. We estimate volumes and weights in the same way, by visual means based on what we have learned by past experience.

Since we have been brought up on the U.S. Customary System of measures, we think in these units, but by training ourselves, we can also learn to think of measurements in metric units just as the people in most other countries do.

In the experiments in this unit we will think primarily in metrics, pretending that customary units do not exist for us, just as if we lived in a country that has converted completely to the metric system or metricated.

You will see how quickly you can begin to visualize sizes in the metric system with a little practice.

## LENGTH AND WIDTH

The unit of length in the metric system is the meter. All other units of length are based on the meter.

| Unit | Symbol | Quantity |
|---|---|---|
| meter | m | 1000 millimeters, 100 centimeters or 10 decimeters |
| millimeter | mm | 1/1000 or .001 m |
| centimeter | cm | 1/100 or .01 m |
| *decimeter | dm | 1/10 or .1 m |
| kilometer | km | 1000 m |

*The decimeter is not used as commonly as the other units but is useful in many instances.

Notice that all the units are related to each other by the factor 10. This is because the metric system is a decimal or base-10 system.

The metric system is also referred to as the mks system (meter, kilogram, second).

Note that the symbols are not followed by a period and are not pluralized with an "s" when quantities of more than 1 are expressed.

**Experiment 1.** Examine your 15 cm ruler. The centimeter is divided into 10 equal parts or millimeters.

Take your diagram sheet and note the two strips divided into centimeters—one from 1 to 50 cm and the other 51 to 100

cm—separated by a center line.

Now cut out the two 50 cm strips from your diagram and paste them together at line AB to make a meter stick. You may wish to reinforce it with a backing of cardboard. Note that a meter contains 100 cm or 1000 mm.

To prevent yourself from referring to the inches in your 15 cm ruler, cover the inch scale with adhesive tape or other removable opaque tape.

With your 15 cm ruler measure the length and width of one of your paper clips in millimeters. What is the width of the wire? Knowing that the wire is 1 mm in width, you can visualize a width of 2 mm or 3 mm.

What is the thickness of this booklet? Estimate it first and then measure it. Do you come close in your estimation?

Measure a variety of small objects, such as buttons, erasers, keys, and paper clips of various sizes. After you have measured a number of them, you will find that you will be able to estimate their sizes fairly closely in millimeters and centimeters. Have a friend show you several small objects that you have not measured and see how well you can estimate their dimensions.

**Experiment 2.** Measure the width and

length of this booklet in millimeters. It is about 76 mm wide and 125 mm long.

Express the measurements in centimeters. To do this you would simply divide by 10 to get 7.6 cm by 12.5 cm. To convert millimeters into decimeters divide by 100 = .76 dm x 1.25 dm, and for meters divide the number of millimeters by 1000 = .076 m x .125 m.

You will observe that to convert millimeters to centimeters, the decimal point is moved one place to the left, to change to decimeters, two places to the left, and to get meters, the decimal point is moved three places to the left.

See how easy it is to change units from one to another in the metric system.

**Experiment 3.** Measure the length and width of one of your polyethylene bags in centimeters. Convert your findings into millimeters.

To do this multiply the centimeters by 10 or move the decimal point one place to the right, adding zero if necessary.

Now express your results in centimeters in decimeters and meters. To get decimeters from centimeters divide by 10 or move the decimal point one place to the left. To obtain meters divide the centimeters by 100 or move the decimal point two positions to the left.

Measure the leaflets in this unit in decimeters. Convert your results into millimeters, centimeters and meters.

Just remember that 1 dm = 100 mm = 10 cm = 0.1 m.

Be sure you move the decimal point in the correct direction.

When converting larger units into smaller units (for example, centimeters into millimeters) multiply or move the decimal point the proper number of places to the right. When converting smaller units into larger (for example centimeters into meters) divide or move the decimal point the proper number of places to the left.

Measure the length, width and thickness of books of different sizes in centimeters and convert your results into millimeters, decimeters and meters. You can always check your conversions by actual measurement.

Find the lengths of spoons, forks, knives, diameters of pots and pans, plates and saucers and other articles in your home until you can visualize their sizes in metric units. The more objects you measure the more facility you will acquire.

How many centimeters long are your palms, your feet, fingers? Compare them

with those of your friends. How much difference in millimeters do you find?

**Experiment 4.** Now take your meter stick and hold it up against your body noticing the height of a meter. How many centimeters tall are you? What is the measurement in meters?

Measure the height of different members of your family and of your friends. Soon you will be able to estimate heights in meters.

Since a centimeter is 1/100 of a meter, if a child is one meter plus 5 centimeters tall, he would be 1.05 m or 105 cm in height; or if 1 m and 23 cm tall, he would be 1.23 m or 123 cm in height. Always check your decimals.

Measure the height of the wall from the floor to the ceiling, the height of a door, the length and width of windows, lamps, pictures on the walls and other large objects.

Can you now visualize John's height in the story?

**Experiment 5.** How many meters wide is the floor in your living room? How long? What is the length of curtains or drapes in your living room?

Convert the number of meters into millimeters, centimeters and decimeters. All you need to do is multiply by 1,000,

100 and 10 respectively to make the conversions.

Would the size rug mentioned in the story be suitable for your living room?

**Experiment 6.** Now take a piece of string and wind it around your wrist once. Cut the string exactly so that the two ends meet. Place the length of string on your meter stick and note the measurement. What is the circumference of your wrist? In the same way, measure the circumference of your head and neck in centimeters.

What are your chest, waist and hip measurements in centimeters? They may seem large when stated in centimeters, but just as in other measurements if you have a waist of say 55 cm and it is considered small, then you will visualize 55 cm as a small measurement. Based on this you would know that a waist measurement of 100 cm would be quite large.

**Experiment 7.** Go outdoors and measure the height of various bushes and plants. Can you now visualize a crocus 6 cm tall?

Would you be able to see over a hedge 1¾ meter high?

**Experiment 8.** Some lengths are better expressed in one unit than another. For example, you may wish to state a meas-

urement as 1.25 meter rather than 125 cm or 1250 mm; 11 mm rather than 1.1 cm or .011 m. In expressing any units, convenience would be your guide, just as it may be more descriptive to say 6 x 9 inches rather than ½ foot by ¾ foot, when giving the size of a sheet of paper or a book.

Learn to interchange one unit for another quickly and with ease and to visualize the same size whether expressed in millimeters, centimeters, decimeters or meters.

Change the dimensions given below so that the units will be the same in each pair. Then convert them to other pairs of similar units. For example, 1.5 m x 1000 mm would equal 1.5 m x 1.0 m, 150 cm x 100 cm, 1500 mm x 1000 mm and 15 dm x 10 dm.

500 cm x 3000 mm
10.6 cm x .003 m
20.31 m x 90.73 cm
65.34 m x 3430.10 cm

Make up exercises of your own. The more you practice the more fluency you will achieve.

**Experiment 9.** In the metric system, distances are measured in kilometers. As

you know one kilometer is equal to 1000 meters. It is difficult to visualize such a length, so here we will mention that a kilometer is .62 mile, just over a half a mile.

Learn to think of distances in kilometers. How far away from your home is your school in kilometers? How many kilometers is it from your home to the city limits?

**Experiment 10.** Look at a road map or any map in an atlas and notice the scale given for measuring distances in miles. Measure the scale in millimeters and then calculate from this how many millimeters represent 1 kilometer. If 25 mm represents 1 mile then

$$\frac{1 \text{ mile}}{25 \text{ mm}} = \frac{.62 \text{ mile}}{x}$$

$$x = 25 \text{ times } .62$$

$$x = 15.5 \text{ mm per kilometer}$$

Now find the number of kilometers from your city to others in various parts of the U.S. using your millimeter scale.

**Experiment 11.** Cut out the speedometer scale calibrated in both miles and kilometers from your diagram sheet. If your parents will allow you to do so,

paste it on the dashboard of your car.

Would you be breaking the speed limit on a city street if you traveled at 80 km per hour? What is the speed limit in kilometer on the superhighways in your area?

Observe the various speed limits for different roads in your neighborhood and learn to think of them in kilometers per hour.

## AREA

We are now familiar with measurements of length in meters, decimeters, centimeters, millimeters and kilometers.

Let us consider the area of a surface. The area is obtained by multiplying the

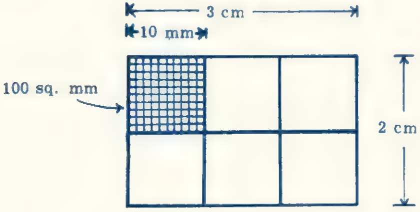


**Fig. 1**

width times the length and is expressed in squares.

**Experiment 12.** Draw a square 1 cm by 1 cm. Its area is 1 square centimeter or 1 $cm^2$.

Now draw a rectangle 2 cm x 3 cm and mark off the centimeters (Fig. 1).

You can see that the area contains six square centimeters. How many square millimeters would it contain? Each square centimeter is equal to 100 $mm^2$.

To convert square centimeters into square millimeters you would therefore have to multiply by 100.

How many square centimeters are there in 1 $dm^2$?

How many square centimeters in area is the cover of this booklet? Square millimeters?

**Experiment 13.** With a string mark off an area 1 m by 1 m on the floor. Notice its dimensions. What is the area of the floor in your living room in square meters? In square decimeters?

How many square meters in a rug 3 m x 4 m in size? How many square decimeters?

Measure any scatter rugs you may have in your home and find their areas in meters. Now look at several rugs that

you have not measured. Can you estimate their areas?

What is the total area of the walls in your living room? Can you estimate the area of the windows in square meters? If you can now visualize the length of a meter, you should have little difficulty in estimating areas.

**Experiment 14.** The area of land is measured in ares and hectares in the metric system. One are (a) is equal to 100 $m^2$, or an area 10 m x 10 m, and one hectare (ha) is equal to 100 a.

How many square meters does a hectare cover?

If you can, measure out an area 10 x 10 m to visualize the size of an are.

How many ares of floor space does your home or apartment occupy?

## VOLUME

Volume is the amount of space a substance occupies and is expressed in cubes.

In the metric system small volumes are measured in cubic centimeters ($cm^3$). The volume is found by multiplying the width times the length times the depth or height.

One cubic centimeter therefore is 1 cm wide x 1 cm long x 1 cm high.

**Experiment 15.** To see the size of a cubic centimeter let us fold one out of

paper. Draw a square 3 cm x 3 cm (Fig. 2).

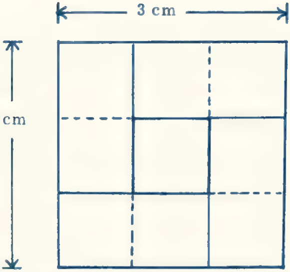


**Fig. 2**

Cut out the square piece and slit along the dotted lines and fold along the solid lines. Paste the sides together and you will have a tiny 1 $cm^3$ box open at the top (Fig. 3).

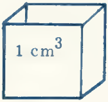


**Fig. 3**

To observe the amount of 1 $cm^3$ of a substance, fill the cube with salt. Pour the crystals into a teaspoon. How many cubic centimeters of salt will make a level teaspoonful? How many cubic centimeters will fill a tablespoon?

Fold boxes of various cubic centimeter dimensions so that you can visualize their volumes.

How many cubic centimeters in a cube of sugar?

**Experiment 16.** Now construct a cube measuring 10 centimeters or 1 decimeter on each side. The cube will have a capacity of 1 $dm^3$ or 1000 $cm^3$, and is equal to 1 liter (1), the most common liquid measure in the metric system. One liter is also equal to 1000 milliliters (ml). Therefore 1 $cm^3$ is equal to 1 ml and the volumes 1 liter, 1 $dm^3$, 1000 $cm^3$ and 1000 ml are equal to each other.

**Experiment 17.** Measure the sides of a half gallon milk carton. You will find that the measurement is about 9.5 cm on each side. Allow 1 mm for the thickness of the container wall, to get an actual internal measure of 9.3 cm for each side.

Now measure 11.6 cm from 1 mm above the bottom of the carton and draw a line across the carton at this point. The volume of the container up to this line

is aproximately one liter.

$$9.3 \times 9.3 \times 11.6 \text{ cm} = 1003 \text{ cm}^3$$

You now have an idea of the size of the 2 liter carton of milk Mrs. Smith purchased at the grocery store.

How many glasses will a liter of milk fill? How many liters of milk a week does your family consume?

**Experiment 18.** Divide a liter of water into two exact half portions. Then divide one of these halves into two equal parts. From these volumes you can visualize the amount of one-half liter or 500 ml, ¼ liter or 250 ml.

**Experiment 19.** Measure the full length of the half gallon milk carton and determine the number of cubic centimeters it holds.

**Experiment 20.** In metric countries gasoline is measured in liters. Can you calculate how many kilometers per liter your car travels?

## MASS

The base unit of mass or weight is the kilogram (kg) equal to 1000 grams (g). One gram is defined as the weight of 1 $cm^3$ of water at its maximum density. The unit for very small amounts is the

milligram (mg) equal to 1/1000 g.

**Experiment 21.** Each of the paper clips in your unit weighs just about one gram. Note how little a weight of one gram is.

Now let us see how much water is equal to one gram.

Make a simple balance. Cut a strip of paper about 20 cm long by 1 cm wide. Paste the strip on a piece of cardboard the same size. Take a piece of strong thread about 30 cm long. At one end make a loop using a slip knot and pass the strip (the beam of your balance)

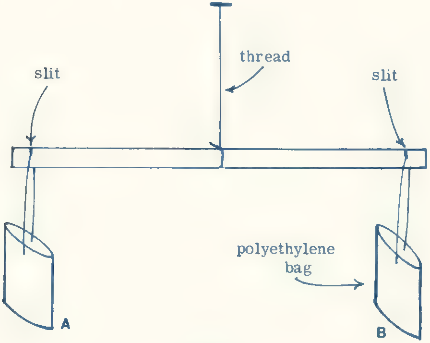


**Fig. 4**

through the loop. Suspend the beam from a stable projection, adjusting the thread until the beam is exactly horizontal. The arms of the balance will then be in equilibrium. Tighten the knot to hold the beam securely (Fig. 4).

Make a handle for each of your two polyethylene bags with sewing thread about 20 cm long. Pass a thread through the center of each lip about 1 cm from the edge (Fig. 5).

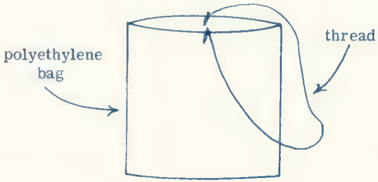


**Fig. 5**

Place a bag on each arm of the beam about 3 cm from the end. Adjust the bag until the beam is again in equilibrium. Then make a tiny slit in the arm at the point of suspension of each bag to hold the thread securely (Fig. 4).

Place a paper clip in bag A at the left while supporting the beam lightly

since it will become unbalanced. With a teaspoon or an eyedropper, gradually add water to bag B on the right until the balance is again in equilibrium. You will then have about one gram of water in the bag, or about 1 $cm^3$. One gram of water as you can see is a very small amount. If you poured the gram of water into a 1 $cm^3$ container, it would completely fill it, assuming that the measurements are precise. If you would like to check this, make a 1 $cm^3$ container out of aluminum foil, like the paper cube in Experiment 15, but fold up the sides without cutting them. Does a gram of water fill it?

Add the second paper clip to bag A and put another gram of water into bag B.

Remove the paper clips from bag A and balance the water with sugar. Note the volume of 2 g of sugar.

Place the two paper clips in bag A containing the sugar and add water to bag B to balance the added weight. You now have 4 g of water. Remove one paper clip and add sugar to equalize the weight. Place the paper clip into bag A again and add another gram of water to bag B. Now you have 5 ml of water.

**Experiment 22.** Carefully pour the

water into a teaspoon. Is 5 ml about equal to one teaspoon in volume?

NOTE: If you plan to use additional paper clips in designing other experiments be sure to check their weights. Not all paper clips of this size weigh 1 g.

**Experiment 23.** If 1 g of water fills 1 ml of space, then one kilogram of water will fill one liter. One liter of water therefore weighs one kilogram.

Weigh the empty half-gallon milk carton. Fill the carton with 1 liter of water. Place the kilogram of water on a scale and note its weight, deducting the weight of the carton. It will be about 2.2 pounds.

Weigh yourself converting the pounds into kilograms. Calculate the weight of your friends in kilograms. You will then be able to visualize John's weight. Is he fat, thin or just about right?

Can you visualize the size of a 250 ml bottle of hand lotion, a 500 g loaf of bread, 2½ kg of hamburger?

## TEMPERATURE

Temperature is measured in degrees Celsius (°C) for everyday use in the metric world. Most of you are familiar with the Celsius scale although you may not use it to express environmental or body temperatures.

At the bottom of the leaflet "All You Will Need to Know About Metric" is the temperature scale given in both Celsius and Fahrenheit.

The normal body temperature as you can see is 37 °C and a comfortable environmental temperature would be about 25 °C.

**Experiment 24.** If you have a thermometer in your home that does not have a Celsius scale, you can make one to fit it so that you can read temperatures directly in degrees Celsius.

Each Celsius degree is equal to 1.8 degrees F.

Paste a strip of paper or put some adhesive tape on the thermometer alongside the Fahrenheit scale.

Draw a line at 32 °F on the paper and mark it 0. Then make a mark at each 1.8 °F interval to indicate 1 °C. Write in the degrees C as space permits.

Note the temperature each day in degrees Celsius only and soon Celsius temperatures will have the same significance for you as degrees Fahrenheit.

The experiments in this unit have helped you become more familiar with the language of a metric world and to think in metric units.

**Experiment 25.** Read the narrative at

the beginning of this booklet again and see if you can now better visualize the quantities given. Do you feel more comfortable with metric units?

**Experiment 26.** Now look at your Metric Conversion Card containing conversions to metric measures and from metric measures.

How many of these metric units can you now visualize without referring to the customary units?

Keep the card with you and by continuing to think in metric terms wherever you can, you will be well prepared for the day when the United States decides to completely metricate.

You may wish to read more about the metric system and how it will affect our lives. The following sources will be helpful to you.

*Prepare Now for a Metric Future*, Frank Donovan, Weybright and Talley, New York.

*U. S. Metric Study Report*, U. S. Department of Commerce, National Bureau of Standards, Catalog No. C 13.10.345, U. S. Government Printing Office, Washington, D. C. 20402 ($2.25).

For information about the metric

system you can write to:

Metric Information Office, National Bureau of Standards, Washington, D. C. 20234.

Metric Association, Inc., 2004 Ash St., Waukegan, Ill. 60085.

This unit was prepared with the cooperation of the National Bureau of Standards, Washington, D. C. Appreciation is expressed to NBS for their participation and for providing the leaflets, "Brief History of Measurement Systems" and "All You Will Need to Know About Metric," the 15 centimeter ruler, the conversion card and paper clips.

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# All You Will Need to Know About Metric

## (For Your Everyday Life)

# 10

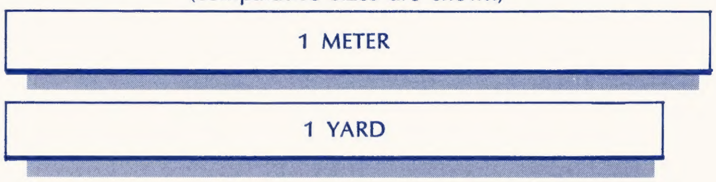
### Metric is based on Decimal system

The metric system is simple to learn. For use in your everyday life you will need to know only ten units. You will also need to get used to a few new temperatures. Of course, there are other units which most persons will not need to learn. There are even some metric units with which you are already familiar: those for time and electricity are the same as you use now.

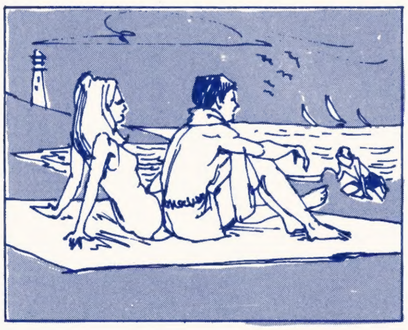
## BASIC UNITS

**METER:** a little longer than a yard (about 1.1 yards)
**LITER:** a little larger than a quart (about 1.06 quarts)
**GRAM:** about the weight of a paper clip

(comparative sizes are shown)




25 DEGREES FAHRENHEIT

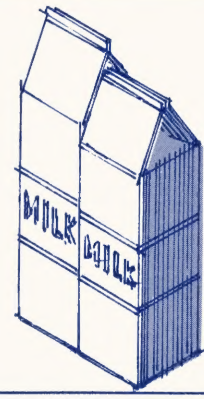


25 DEGREES CELSIUS

### COMMON PREFIXES
(to be used with basic units)

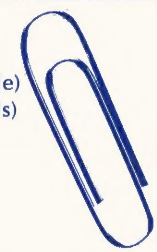
**Milli:** one-thousandth (0.001)
**Centi:** one-hundredth (0.01)
**Kilo:** one-thousand times (1000)

**For example:**
1000 millimeters = 1 meter
100 centimeters = 1 meter
1000 meters = 1 kilometer



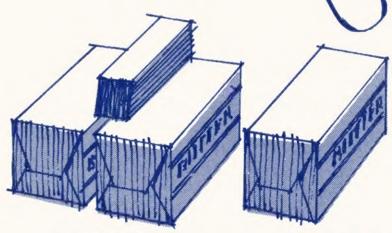

### OTHER COMMONLY USED UNITS

| | | |
|---|---|---|
| **Millimeter:** | 0.001 meter | diameter of paper clip wire |
| **Centimeter:** | 0.01 meter | width of a paper clip (about 0.4 inch) |
| **Kilometer:** | 1000 meters | somewhat further than ½ mile (about 0.6 mile) |
| **Kilogram:** | 1000 grams | a little more than 2 pounds (about 2.2 pounds) |
| **Milliliter:** | 0.001 liter | five of them make a teaspoon |

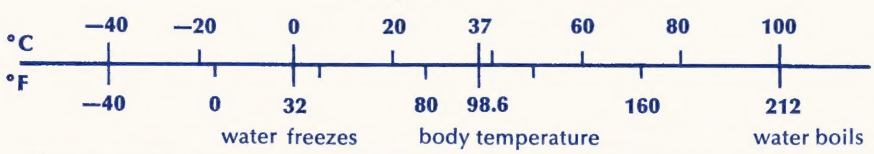


### OTHER USEFUL UNITS

**Hectare:** about 2½ acres
**Tonne:** about one ton




### TEMPERATURE
degrees Celsius are used

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UNITED STATES DEPARTMENT OF COMMERCE
PETER G. PETERSON, Secretary
NATIONAL BUREAU OF STANDARDS / LAWRENCE M. KUSHNER, Acting Director

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## Brief History of

# MEASUREMENT SYSTEMS

## with a Chart of the Modernized Metric System

*"Weights and measures may be ranked among the necessaries of life to every individual of human society. They enter into the economical arrangements and daily concerns of every family. They are necessary to every occupation of human industry; to the distribution and security of every species of property; to every transaction of trade and commerce; to the labors of the husbandman; to the ingenuity of the artificer; to the studies of the philosopher; to the researches of the antiquarian, to the navigation of the mariner, and the marches of the soldier; to all the exchanges of peace, and all the operations of war. The knowledge of them, as in established use, is among the first elements of education, and is often learned by those who learn nothing else, not even to read and write. This knowledge is riveted in the memory by the habitual application of it to the employments of men throughout life."*

JOHN QUINCY ADAMS
Report to the Congress, 1821

Weights and measures were among the earliest tools invented by man. Primitive societies needed rudimentary measures for many tasks: constructing dwellings of an appropriate size and shape, fashioning clothing, or bartering food or raw materials.

Man understandably turned first to parts of his body and his natural surroundings for measuring instruments. Early Babylonian and Egyptian records and the Bible indicate that length was first measured with the forearm, hand, or finger and that time was measured by the periods of the sun, moon, and other heavenly bodies. When it was necessary to compare the capacities of containers such as gourds or clay or metal vessels, they were filled with plant seeds which were then counted to measure the volumes. When means for weighing were invented, seeds and stones served as standards. For instance, the "carat," still used as a unit for gems, was derived from the carob seed.

As societies evolved, weights and measures became more complex. The invention of numbering systems and the science of mathematics made it possible to create whole systems of weights and measures suited to trade and commerce, land division, taxation, or scientific research. For these more sophisticated uses it was necessary not only to weigh and measure more complex things—it was also necessary to do it accurately time after time and in different places. However, with limited international exchange of goods and communication of ideas, it is not surprising that different systems for the same purpose developed and became established in different parts of the world—even in different parts of a single continent.

### The English System

The measurement system commonly used in the United States today is nearly the same as that brought by the colonists from England. These measures had their origins in a variety of cultures—Babylonian, Egyptian, Roman, Anglo-Saxon, and Norman French. The ancient "digit," "palm," "span," and "cubit" units evolved into the "inch," "foot," and "yard" through a complicated transformation not yet fully understood.

Roman contributions include the use of the number 12 as a base (our foot is divided into 12 inches) and words from which we derive many of our present weights and measures names. For example, the 12 divisions of the Roman "pes," or foot, were called *unciae*. Our words "inch" and "ounce" are both derived from that Latin word.

The "yard" as a measure of length can be traced back to the early Saxon kings. They wore a sash or girdle around the waist—that could be removed and used as a convenient measuring device. Thus the word "yard" comes from the Saxon word "gird" meaning the circumference of a person's waist.

Standardization of the various units and their combinations into a loosely related system of weights and measures sometimes occurred in fascinating ways. Tradition holds that King Henry I decreed that the yard should be the distance from the tip of his nose to the end of his thumb. The length of a furlong (or furrow-long) was established by early Tudor rulers as 220 yards. This led Queen Elizabeth I to declare, in the 16th century, that henceforth the traditional Roman mile of 5,000 feet would be replaced by one of 5,280 feet, making the mile exactly 8 furlongs and providing a convenient relationship between two previously ill-related measures.

Thus, through royal edicts, England by the 18th century had achieved a greater degree of standardization than the continental countries. The English units were well suited to commerce and trade because they had been developed and refined to meet commercial needs. Through colonization and dominance of world commerce during the 17th, 18th,

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and 19th centuries, the English system of weights and measures was spread to and established in many parts of the world, including the American colonies.

However, standards still differed to an extent undesirable for commerce among the 12 colonies. The need for greater uniformity led to clauses in the Articles of Confederation (ratified by the original colonies in 1781) and the Constitution of the United States (ratified in 1790) giving power to the Congress to fix uniform standards for weights and measures. Today, standards supplied to all the States by the National Bureau of Standards assure uniformity throughout the country.

## The Metric System

The need for a single worldwide coordinated measurement system was recognized over 300 years ago. Gabriel Mouton, Vicar of St. Paul in Lyons, proposed in 1670 a comprehensive decimal measurement system based on the length of one minute of arc of a great circle of the earth. In 1671 Jean Picard, a French astronomer, proposed the length of a pendulum beating seconds as the unit of length. (Such a pendulum would have been fairly easily reproducible, thus facilitating the widespread distribution of uniform standards.) Other proposals were made, but over a century elapsed before any action was taken.

In 1790, in the midst of the French Revolution, the National Assembly of France requested the French Academy of Sciences to "deduce an invariable standard for all the measures and all the weights." The Commission appointed by the Academy created a system that was, at once, simple and scientific. The unit of length was to be a portion of the earth's circumference. Measures for capacity (volume) and mass (weight) were to be derived from the unit of length, thus relating the basic units of the system to each other and to nature. Furthermore, the larger and smaller versions of each unit were to be created by multiplying or dividing the basic units by 10 and its multiples. This feature provided a great convenience to users of the system, by eliminating the need for such calculations as dividing by 16 (to convert ounces to pounds) or by 12 (to convert inches to feet). Similar calculations in the metric system could be performed simply by shifting the decimal point. Thus the metric system is a "base-10" or "decimal" system.

The Commission assigned the name *metre* (which we now spell meter) to the unit of length. This name was derived from the Greek word *metron,* meaning "a measure." The physical standard representing the meter was to be constructed so that it would equal one ten-millionth of the distance from the north pole to the equator along the meridian of the earth running near Dunkirk in France and Barcelona in Spain.

The metric unit of mass, called the "gram," was defined as the mass of one cubic centimeter (a cube that is 1/100 of a meter on each side) of water at its temperature of maximum density. The cubic decimeter (a cube 1/10 of a meter on each side) was chosen as the unit of fluid capacity. This measure was given the name "liter."

Although the metric system was not accepted with enthusiasm at first, adoption by other nations occurred steadily after France made its use compulsory in 1840. The standardized character and decimal features of the metric system made it well suited to scientific and engineering work. Consequently, it is not surprising that the rapid spread of the system coincided with an age of rapid technological development. In the United States, by Act of Congress in 1866, it was made "lawful throughout the United States of America to employ the weights and measures of the metric system in all contracts, dealings or court proceedings."

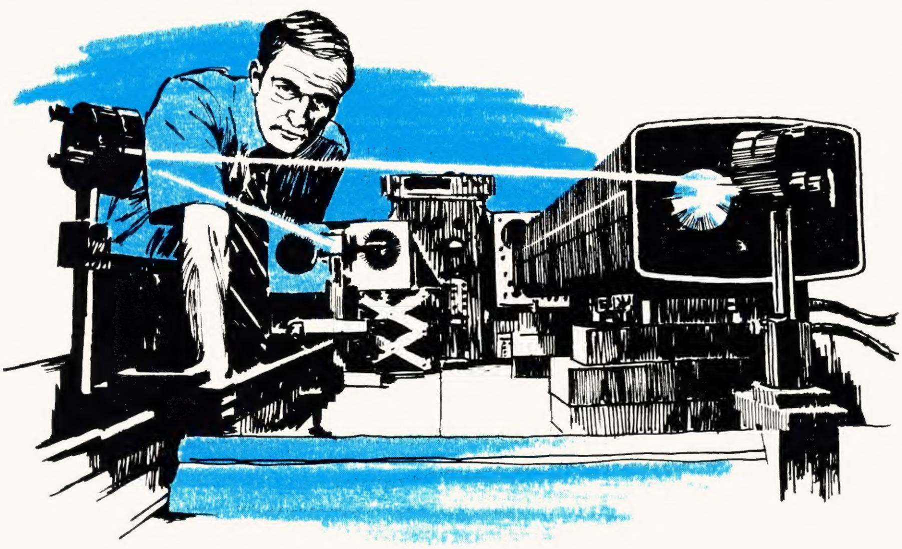
By the late 1860's, even better metric standards were needed to keep pace with scientific advances. In 1875, an international treaty, the "Treaty of the Meter," set up well-defined metric standards for length and mass, and established permanent machinery to recommend and adopt further refinements in the metric system. This treaty, known as the Metric Convention, was signed by 17 countries, including the United States.

As a result of the Treaty, metric standards were constructed and distributed to each nation that ratified the Convention. Since 1893, the internationally agreed-to metric standards have served as the fundamental weights and measures standards of the United States.

By 1900 a total of 35 nations—including the major nations of continental Europe and most of South America—had officially accepted the metric system. Today, with the exception of the United States and a few small countries, the entire world is using predominantly the metric system or is committed to such use. In 1971 the Secretary of Commerce, in transmitting to Congress the results of a 3-year study authorized by the Metric Study Act of 1968, recommended that the U.S. change to predominant use of the metric system through a coordinated national program. The Congress is now considering this recommendation.

The International Bureau of Weights and Measures located at Sevres, France, serves as a permanent secretariat for the Metric Convention, coordinating the exchange of information about the use and refinement of the metric system. As measurement science develops more precise and easily reproducible ways of defining the measurement units, the General Conference of Weights and Measures—the diplomatic organization made up of adherents to the Convention—meets periodically to ratify improvements in the system and the standards.

In 1960, the General Conference adopted an extensive revision and simplification of the system. The name *Le Système International d'Unités* (International System of Units), with the international abbreviation SI, was adopted for this modernized metric system. Further improvements in and additions to SI were made by the General Conference in 1964, 1968, and 1971.



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